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SUMMARY

A brief study is made of a closed-circuit television mounted in a trainer-type airplane to provide forward view during landing. The results of 45 landings by seven pilots under good visual conditions but with the pilot entirely dependent on the television for vision showed that television provided adequate forward view during the approach, flare, and ground roll. In addition, three take-offs were made which showed that television provided adequate forward view during the ground roll and climb to about 500 feet. Some problems connected with the use of the television for forward view are discussed and some recommendations are made for a practical system.

INTRODUCTION

The new designs for future very high performance aircraft have led to the suggestion that other means of providing forward vision than the conventional windshield may be needed for landing. One proposal for obtaining forward vision is by the use of closed-circuit television. Information was needed, however, to determine the requirements for a usable airborne closed-circuit television system and to resolve any airplane operating problems connected with the two-dimensional or flat-view field provided by the television monitor. Also, information was needed on the visual cues and field of view required for simulator investigations of landing problems of future aircraft and space vehicles.

Because landing is the most critical phase of airplane operation, a brief investigation was made late in 1958 of closed-circuit television to provide forward vision for landing. This paper gives the results of 45 landings by seven pilots with a trainer-type airplane using closed-circuit television for forward vision.

EQUIPMENT

A standard commercial closed-circuit television set which included a monitor, control box, vidicon camera, and connecting cables was installed in a trainer-type airplane (fig. 1). The 12-inch monitor was mounted in place of the rear cockpit instrument panel and the control box was installed in the baggage compartment. The vidicon camera was installed in a pod that was attached under the left wing at the bomb shackle location. This placed the vidicon-camera lens 5 feet below and 8 feet to the left of the position where the rear cockpit pilot's eyes would normally be during landing. For the first two landings, a 15-mm focal-length lens giving a 34° angle of view was used on the vidicon camera. However, with this lens mechanical difficulties made it impossible to get the vidicon camera into focus and consequently a 1-inch focal-length lens with a 21.5° angle of view was used for the remainder of the landings.

A separate 110-volt, 60-cycle, 750-volt ampere inverter, mounted just forward of the battery location in the rear of the fuselage, was used as a source of power for the television equipment. All the closed-circuit television electrical tuning controls were located either on the control box or rear of the monitor except that the controls for vertical hold, horizontal hold, contrast, brightness, and vertical alinement were located on the front of the monitor. The vidicon-camera lens was set manually prior to flight for the various light conditions.

Lack of space did not permit any engine instruments to be installed in the rear cockpit, and the only flight instruments provided were an airspeed indicator and altimeter, which were installed above the monitor. The entire rear cockpit was covered by a hood which prevented any outside vision. A 16-mm gun camera was placed just to the right of the pilot's head to photograph the monitor and another 16-mm gun camera was installed in the wing camera compartment.

TESTS

The vidicon-camera-lens setting could not be changed in flight to compensate for large variations in light intensity; therefore, all the landing tests except two, which were made with 0.2 to 0.3 cloud cover, were made under uniform light conditions. On sunny days, the landing tests were made with the sun either overhead or behind the pilot to minimize the light reflection from the concrete runway so that it could be compensated for by the fine-tune contrast and brightness controls available to the pilot. Initially, an attempt was made to fly an entire standard left-hand landing traffic pattern. However, the light variations were too large to be compensated for by the pilot's television controls and the landing tests were limited to final approach, flare, and touchdown.

Two pilots were aboard during all tests. The forward pilot was the safety pilot and the rear pilot, under the hood, was the test pilot. For these tests, the safety pilot turned the airplane onto the final approach path and set the propeller-governor control at approximately the correct setting. The airplane controls were then taken over by the test pilot, who proceeded to establish his approach path.

The seven test pilots used for these tests were permitted to use any landing technique they desired. For the 45 landing tests in this investigation, all used a nearly constant glide-path-angle final-approach technique and all the pilots except one used the same flare technique. Glide-path angles which ranged from about 3° to 5° were tried, with the 5° angle being used most often. For safety, each pilot was permitted to make as many orientation landings without the hood as desired. Two pilots used two orientation landings, three pilots did not use any orientation landings, and two pilots used one orientation landing. Nineteen of the 45 landings were made with cross-wind components from about 5 to 10 knots in order to determine their effect on the landings. Motion pictures were taken of the monitor and forward view from the airplane. For additional information, three take-offs, one each by three pilots, were made with the television monitor used for forward view.

DISCUSSION

The results of this investigation are presented in four parts: final approach, flare and ground roll, take-off, and equipment requirements.

Final Approach

The final approaches started at distances of 2 to 4 miles from the runway and were made with constant glide-path angles which ranged from 3° to 5°. With the approach speed of about 90 knots, the final approaches were between 1 and 2 minutes in duration.

Both the motion pictures of the monitor and comments of all the pilots indicate that the more important visual cues used during a normal approach could be obtained from the monitor picture. Some difficulty was experienced because the horizon, which was desired for attitude reference, was poorly defined as a result of the limited depth of focus and appeared curved because it was not on the optical axis of the vidicon camera. The loss of the horizon as an attitude reference was not limiting because other cues such as the position of the runway on the monitor picture could be used instead for attitude reference.

The depth of focus was, at best, considered only fair by all pilots, and their evaluation was substantiated by evidence from the motion pictures of the monitor for all test landings. The theoretical resolution of the monitor picture was about 2.5 minutes of arc. However, the measured resolution of the picture, as determined from the width of the field of view at the distance from the lens at which two lines 5 feet apart could be distinguished, varied between 7 and 11 minutes of arc. Although it was possible to make reasonable final approaches with this range of resolution, all pilots were of the opinion that for a practical operational system the picture should have a resolution estimated to be about 3 minutes of arc or better. Because of the limited depth of focus, inadequate resolution, and, at times, poor picture contrast and brightness due to variations in light intensity discussed earlier, height estimation from near foreground objects was, at best, marginal. This, in turn, made it difficult for the pilot to maintain an accurate glide path to the point of flare.

All pilots indicated that the 21.5° angle of view was adequate for establishing and maintaining a desired glide path for all approaches made. However, no attempt was made to determine whether the angle of view would be adequate if large airplane attitude changes were required during the approach.

The use of a glide-path angle within the range of 3° to 5° was satisfactory for the landings. For 20 of the approaches, there were crosswinds ranging from about 5 to 10 knots and all pilots reported that they had no problem in maintaining directional alinement with these crosswinds.

From these tests it can be concluded that good approaches for landing can be made consistently by using television for forward view.

Flare and Ground Roll

Six of the pilots used a normal flare technique but one pilot started his flare at about the 20-foot height indication on his altimeter. This technique is similar to that used in night landings without the use of lights. There was a tendency to flare the airplane somewhat prematurely on the earlier landings made by each pilot until they compensated for the location of the vidicon camera 5 feet below the accustomed eye level. Large nose-up attitudes near stall for landing had to be avoided to prevent loss of view of the runway on the monitor screen.

The motion pictures of the monitor and comments of all the pilots indicate that visual cues for flaring of the airplane and roll-out after touchdown could be obtained from the monitor picture. The only difficulty reported by all pilots was in estimating height within about 5 feet during the last 10 feet from the runway. This difficulty in exact height estimation was thought to be due partly to the narrow 21.5° angle of view, which limited the peripheral vision, but more strongly to the marginal resolution and depth of focus of the monitor picture. The limit of the peripheral vision can be realized from the fact that the nearest point at which the pilot was able to see the side of the runway was about 400 feet ahead of the airplane. The texture of the landing surface, such as the division strips in the concrete, center-line markings, and tire skid marks, were the primary source of information used by the pilots during the flare and touchdown. This information appeared to be adequate except for the judgment of height previously mentioned. Where landing touchdown was attempted solely on the basis of exact height estimation, some hard landings and a wide variation in touchdown point resulted. However, use of other pilot techniques and visual cues allowed good landing touchdown to be made but what effect they had on the position of the touchdown point is not known. One such technique was to accept a finite rate of descent to touchdown. Thus, the lack of accurate height judgment could be offset without resulting in large aircraft attitude changes or excessive floating. The touchdown impact was not unusually hard in these cases and was much less hard than those which sometimes resulted when the pilot misjudged the height while attempting to flare to lower rates of descent. After touchdown, the angle of view was adequate for the ground roll and subsequent taxiing.

The 7 to 11 minutes of arc resolution of the monitor picture was adequate in general during the flare and ground roll. However, it was not sufficient to allow effective judgment of the texture of the ground surface as an aid in accurate height determination for the touchdown. Any drift of the airplane due to the crosswinds up to 10 knots could be corrected easily and quickly during the flare and touchdown. The crosswinds presented no problem during the ground roll and subsequent taxiing.

Although pilots experienced some difficulty in flaring the airplane as accurately as desired with this equipment, these tests indicate that an airplane can be landed and controlled on the runway after touchdown by using television for forward view.

Take-Off

For additional information, three take-offs were made using the television for forward vision. No problems were encountered with directional alinement during the ground roll and climb to about 500 feet where the airplane was leveled. After lift-off, pitch reference became progressively less satisfactory as a result of the pilots' inability to define the horizon and because of the narrow angle of view.

Equipment Requirements

For the two approaches made with a cloud cover of 0.2 to 0.3, the large variations in light intensity caused by the changing cloud cover required considerable adjustment of the brightness control on the monitor. The pilot found this manipulation objectionable and, in many instances, impossible because of the workload connected with flying the airplane. For a practical television system, the vidicon camera must have automatic light control.

As an aid in height determination, it would be advantageous for the pilot to have a focus control for the vidicon-camera lens to bring near objects into critical focus as touchdown is approached. It is not known what caused the poor depth of focus.

CONCLUDING REMARKS

A brief study has been presented of the use of a closed-circuit television to provide forward view during aircraft landing. The results of 45 landings by seven different pilots under good visual conditions but with the pilot entirely dependent on the television for vision showed that television provided adequate forward view during the approach, flare, and ground roll. In addition, the results of three take-offs showed that television provided adequate forward view during the ground roll and climb to about 500 feet. This study indicated that a practical television system for aircraft should provide automatic light control and that the pilot should be provided with a focus control for the vidicon camera.

Langley Research Center,
National Aeronautics and Space Administration,
Langley Station, Hampton, Va., October 31, 1963.

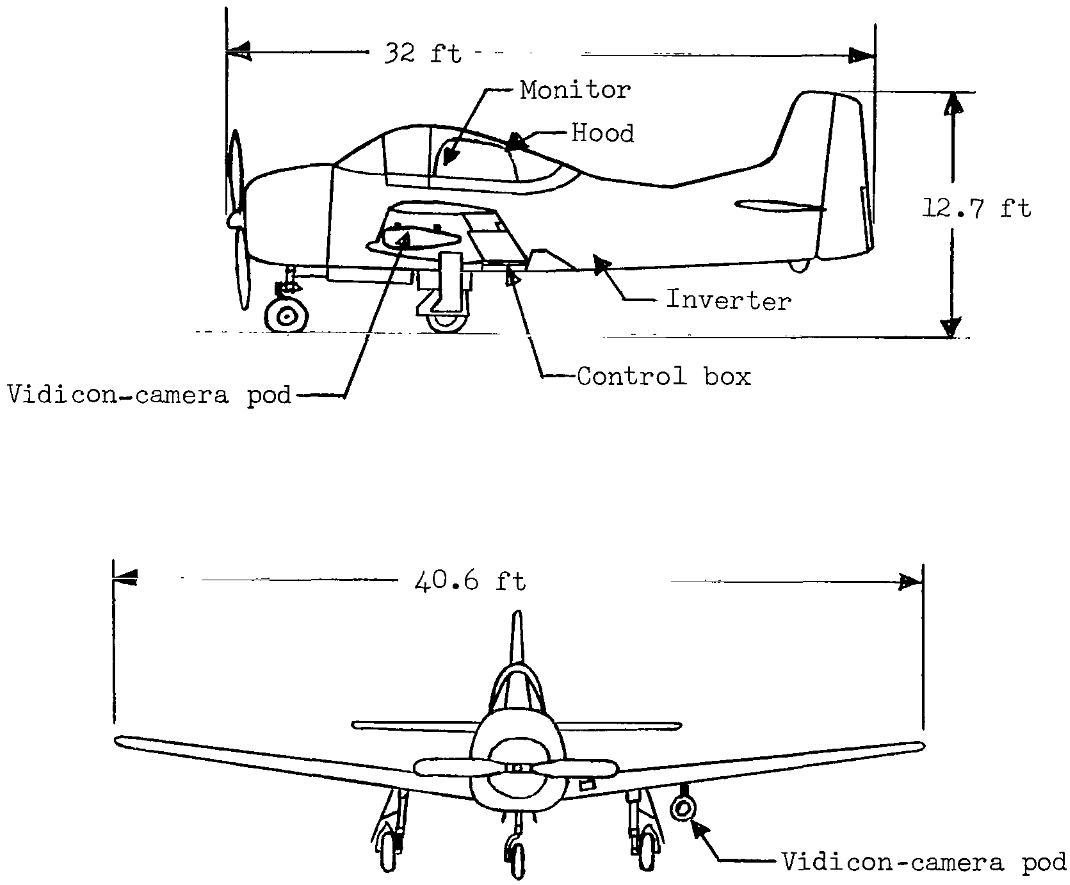

Figure 1.- Sketch of the trainer airplane and location of the closed-circuit television equipment.

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